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Effect of Se treatment on the volatile compounds in broccoli

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ABSTRACT

Broccoli contains high levels of bioactive compounds but deteriorates and senesces easily. In the present study, freshly harvested broccoli was treated with selenite and stored at two different temperatures. The effect of selenite treatment on sensory quality and postharvest physiology were analyzed. Volatile components were assessed by HS-SPME combined with GC–MS and EN. The metabolism of Se and S was also examined. Results indicated that Se treatment had a significant effect on maintaining the sensory quality, suppressing the respiration intensity and ethylene production, as well as increasing the content of Se and decreasing the content of S. In particular, significant differences in the composition of volatile compounds were present between control and Se-treated. The differences were mainly due to differences in alcohols and sulfide compounds. These results demonstrate that Se treatment can have a positive effect on maintaining quality and enhancing its sensory quality through the release of volatile compounds.

1. Introduction

Broccoli (*Brassica oleracea L.var.italica*) is a popular and extensively eaten vegetable worldwide. It contains a high level of bioactive compounds, such as ascorbic acid, total phenols, flavonoids, and glucosinolates. Freshly harvested broccoli, however, deteriorates and senesces rapidly after harvest when left at ambient temperatures. The loss in quality is reflected in the yellowing of florets and a rapid decrease in the nutritional content (Nishikawa et al., 2003). Modified atmosphere packaging (MAP) has been reported to maintain, for at least ten days, the visual quality of broccoli, the concentration of the main health-promoting compounds, such as ascorbic acid, carotenoid, chlorophylls pigments, total phenolic, total aliphatic, indole glucosinolates, intact glucosinolates, and reduce weight loss in broccoli florets (Fernández-León, Fernández-León, Lozano, Ayuso, & González-Gómez, 2013; Fernández-León et al., 2013; Jia et al., 2009; Rangkadilok et al., 2002). Packaging broccoli florets in bags composed of polyethylene (PE) film was reported to be the best for extending the shelf life and maintaining the visual quality of broccoli florets (Jia et al., 2009). Broccoli, however, will produce persistent, unpleasant odours and an off-flavour (Kasmire, Kader, & Klaustermeyer, 1974, personal observation). This is likely to have a negative impact on the consumer perception of the quality of the purchased broccoli. Therefore, preventing senescence and the development of an unpleasant odour in broccoli florets is extremely important.

Selenium (Se) is one of the fourteen essential trace elements for humans, that can only be supplied through an external source. The recommended dietary allowance for Se is 55–70 μg/d (Otten, Hellwig, & Meyers, 2006). The maximum safe dietary intake ranges from 600 μg/d to 800 μg/d (Whanger, 2004). Broccoli has been extensively studied because of its tolerance of high levels of Se (Pedrero, Elvira, Cámara, & Madrid, 2007). One of mechanisms of handling excessive Se in Se-tolerant plants is to synthesize Se-containing organic compounds that cannot be incorporated into proteins (Pyrzynska, 2009). Brassica plants can accrue high concentrations of Se concentrations due to their ability to convert selenoamino acids into non-proteogenic amino acids (Lyi et al., 2005a). Selenium can have a significant impact on the quality of fruits and vegetables, after it is absorbed and metabolized by a plant. Song et al. (2015) reported that the cellular content of linolenic acid and sterols increased significantly with increasing levels of selenium, while the content of oleic acid decreased. Squalene increases in cells having low selenium levels and has a tendency to decrease at high selenium levels. Vegetable yields are higher when plants are treated with Se (Hu, Xu, & Pang, 2003), and exhibit better processing characteristics (Turakainen, Hartikainen, Ekholm, & Seppänen, 2006), as well as a lower respiration (Pezzarossa,

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Rosellini, Borghesi, & Kuperh, 2014). Studies, however, have not investigated the effect of Se on the composition and release of volatile compounds from broccoli that has been placed in MAP.

In recent years, gas chromatography-mass spectrometry (GC–MS) and the use of an electronic nose (EN) have been the main methods used to analyze volatile compounds. EN is an instrument that uses chemical sensors to detect volatile compounds and provides a comprehensive fingerprint of scent compounds, while GC–MS is mainly used to quantify the level of individual volatile compounds (Cheng et al., 2015; Papadopoulou, Panagou, Mohareb, & Nychas, 2013). Many studies analyzed and characterized the different volatile compounds in fruits and vegetables using either GC–MS or EN (Huang et al., 2011; Hui et al., 2015; Lopez de Lerma, Bellincontro, Mencarelli, Moreno, & Peinado, 2012).

In the current study, freshly harvested broccoli was treated with selenite (2 mg selenite/kg water) or distilled water (control) and then packaged with MAP. The effect of the selenite treatment on sensory quality and postharvest physiology (respiration intensity and ethylene production) was analyzed. Volatile components were detected using headspace solid phase micro-extraction (HS-SPME) combined with GC–MS and EN. The metabolism of Se and S in broccoli was also examined. The results of the study provide a theoretical basis for clarifying the changes in volatile compounds that occur in Se-treated broccoli.

2. Materials and methods

2.1. Plant material and treatments

Broccoli was harvested 91 days after planting. It was hand-picked at commercial maturity from a greenhouse in Miyun, Beijing, China, and immediately transported to the laboratory. Broccoli heads free of insect pests, disease symptoms, and mechanical damage were selected for use in the experiment. Broccoli heads were soaked in water containing 2 mg/kg selenite (Se treatment) or distilled water (the control) for 20 min. The broccoli was then air dried and 1.5 kg portions were placed in bags made from polyethylene film (thickness 0.03 mm, size 50 mm × 40 mm). The packaged broccoli was stored at either 0 ± 1 °C or 20 ± 1 °C. Samples of the packaged broccoli were taken after different lengths of storage time and immediately frozen in liquid nitrogen and stored at −80 °C until they were analyzed.

2.2. Sensory quality

A panel of eight trained assessors was asked to compare and evaluate all samples. The evaluation parameters included colour, freshness, and odour of the broccoli floret (Table 1). Evaluations were conducted on broccoli florets stored at 20 °C for 2, 4, 6, and 8 days after treatment, and also on broccoli florets stored at 0 °C for 15, 30, 45, and 60 days after treatment.

Table 1
Values (scores) used in the sensory evaluation of broccoli.

Score	Describe standard		
	Colour	Freshness	Odour
100 ~ 75	Fresh green	Fresh and crisp	Fresh fragrance
75 ~ 50	Broccoli floret turning yellow ⩽10%	Slight water loss	Fresh fragrance disappear
50 ~ 25	Broccoli floret turning yellow ⩽30%	Moderate water loss	Slight peculiar smell
25 ~ 0	Broccoli floret turning yellow ⩽50%	Serious water loss	Obvious a foul odour

2.3. Respiration intensity

Each sample (1.5 kg) was placed in a fixed volume sealed glass container for 2 h at the temperature, and then the respiration intensity was measured using a GXH-3051 infrared analyzer (Institute of Physical and Chemical Technology of Beijing JUNFANG, China) according to the protocol described by Wang et al. (2015).

2.4. Ethylene production

Ethylene production was analyzed by gas chromatography (GC) using the protocol described by Kaewsuksaeng, Tatmala, Srilaong, and Pongprasert (2015).

2.5. Electronic nose system

An E-nose system (E-nose, PEN3, Airsense Analytic, GmBH, Schwerin, Germany) equipped with 10 metal oxide gas sensors (MOS sensors) was used. A sample of fresh broccoli florets (2 g) was placed in a 20 ml sealed vial with a PTFE-silicone septum (Supelco, Bellefonte, PA, USA) for 20 min at room temperature. The measurement phase lasted 150 s and the standby phase was activated for 100 s in order to clean the circuit when the measurement was completed. Each analysis was repeated a minimum of three times.

2.6. HS-SPME-GC–MS

A sample of fresh broccoli florets (2.0 g) was placed in a 20 ml sealed vial with a PTFE-silicone septum (Supelco, Bellefonte, PA, USA). The sample was equilibrated for 20 min and then extracted for 40 min at 50 °C using a 65 μm polydimethylsiloxane divinylbenzene (PDMS/DVB) fiber (Supelco, Bellefonte, PA, USA). The fiber was then removed from the vial and inserted into the injection port of the GC–MS apparatus for the analysis of volatile compounds. The volatile compounds were identified on the basis of matching the experimental mass spectra with spectra in a mass spectra library from NIST11. The relative content of each of the identified volatile compounds was calculated on the basis of the percentage of peak area.

GC conditions: The analysis of volatile compounds was performed on a GC–MS apparatus (Shimadzu GC–MS QP2010 plus, Japan). The analytes removed from the fiber were carried out at 250 °C. Analytes were separated in a DB-WAX column (30 m × 0.25 mm × 0.25 μm) by applying the following temperature program: 40 °C for 3 min, raised to 120 °C at 5 °C/min, then increased to 200 °C at 10 °C/min and held for 5 min.

MS conditions: The electron ionization source temperature was maintained at 200 °C; Mass scanning ranged from 35 to 500 *m*/*z*. The flow rate of helium was 1.0 ml/min.

2.7. Total Se and S

Total Se content was determined using a HG-AFS (Beijing Puxi Instrument Co., Ltd., China). Fresh samples (2.00 g) were weighed and placed into glass digestion tubes, acid-digested in 10 ml HNO_3 and 2 ml H_2O_2. The samples were digested in a microwave digestion instrument at 150 °C for 1 h. Then, after cooling, the mixture was transferred into a flask and heated to near dryness on a hot plate (not evaporated to dryness). Subsequently, 5 ml HCl was added into the mixture, and continued to be heated until the solution became clear, colourless, and emitted white smoke. Finally, the samples were then diluted with double-distilled water to 50 ml. Total S content was determined using the Varian ICP-OES analyzer model Vista-MPX (Varian, Palo Alto, CA) according to Lyi et al. (Lyi et al., 2005b).